The Impact of Honeybee Pollination on *Macadamia* (Proteceae) Nut Set

Jane M. Tavares*, Scott Nikaido, Maria Diaz-Lyke, Ethel Villalobos, and Mark Wright.
Department of Plant and Environmental Protection Sciences. College of Tropical Agriculture and Human Resources (CTAHR).
University of Hawaii.

Introduction

Macadamia integrifolia (Proteaceae) is an evergreen tree native to subtropical coastal regions of Australia (Heard 1993). It was brought to Hawaii in 1881 to be used as an ornamental and for reforestation. In 1948 Hawaii produced several varieties of *Macadamia integrifolia* which led to the successful macadamia nut industry Hawaii has developed into today (California Rare Fruit Growers, Inc., 1997).

Macadamia trees produce large numbers of flowers that require insect visitation for adequate fruit set. The local growers frequently supplemented the services provided by feral hives with large numbers of managed colonies of honeybees to increase nut yield. Since the arrival of Varroa destructor in Hawaii beekeepers have lost significant numbers of colonies. Consequently, it is crucial to quantify the impact of honey bee pollination on macadamia production to help farmers determine the number of managed hives needed to maintain adequate yields in their yards.

Macadamia flowers are somewhat unusual in that the pollen is shed from the anthers while the flower still closed and in this way the pollen is transferred to the developing style. As the flower opens, the available pollen is found on mostly on the style and not the anthers. Pollen collecting bees tend to hover checking the styles, while the nectar collecting bees tend to walk over the inflorescences and burrow their heads deep into the flower corolla in search of their nectar reward.

This preliminary study was conducted to document the impact of insect pollination, in particular honeybee visitation, on the nut set of macadamia trees on an Oahu Macadamia orchard.

Materials and Methods

Study site: Experiments were conducted in a Macadamia orchard located at the University of Hawaii Waimanalo Research Station (21˚33' N 157˚71' W) on the island of Oahu, from February 19, 2010 to March 19, 2010. Two cultivars used at the Waimanalo Research Station: 'Kau 344', and 'Keaau 660'.

Experimental design: The experimental treatments for this study were (1) Open Pollination (OP), inflorescences exposed to open pollination and (2) Bee Exclusion (B-Exc), no insect pollination. To compare the effect of open pollination (OP) versus bee exclusion (B Exc) on the nut set levels we selected two types of inflorescences: those with older spent flowers and those with still undeveloped flower buds. Inflorescences located on the distal part of branches were covered with bags measuring 69cm long and 55cm wide constructed from no-seeum mesh netting. Each bag was large enough to cover an average of 4 inflorescences and associated leaves. Flagging tape was used to label each bag and each individual tree.

The Open Pollination (OP) group consisted of 10 bags (44 inflorescences, average 4 inflorescences/bag). We assume that these post-anthesis inflorescences could have been visited by all the possible pollinators and will provide the base line for the natural seed set in the field. The Bee Exclusion (B-Exc) group consisted of 11 bags (34 inflorescences, average 3 inflorescences/bag). All B-Exc inflorescences were bagged as green buds and consequently they had never been visited by bees or other potential insect pollinators. Inflorescences were kept bagged during the early stages of fruit formation to protect them from insect damage, and the initial fruit set that occurred post anthesis was recorded by counting the developing fruits through the net bag mesh.

Pollinators and honeybee behavior: Preliminary bee counts and behavioral observations were made throughout the day to assess the proportions of honeybee foragers that were collecting nectar or pollen. Additionally, a preliminary identification list of insect visitors was compiled.

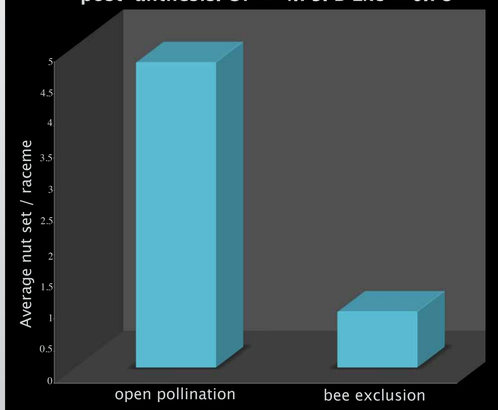
Inflorescences: A total of 24 inflorescences, were measured to nearest millimeter to obtain the average length of an inflorescence. These inflorescences were also used to obtain the average number of flowers per inflorescence.

Statistical analysis: Comparisons between the OP and B Exc groups were analyzed using a Mann-Whitney Sum Rank Test. We also calculated the coefficient of variance describing the variability in length and number of individual flowers/ inflorescence

Additional insect visitors

Two species of Syrphidae: *Allograpta oblique*, and *Ordinia obese*, two species of Ceratopogonidae: *Atrichopogon jacobsoni*, and *Forcipomyia hardyi*, a species of Milichiidae: *Desmometopa spp.*, a Chloropidae: *Conioscinella formosa*, and a Hemiptera currently identified only to family: Psyllidae.

Figure 1. Average nut set per raceme, 14 days post-anthesis. OP = 4.75. B Exc = 0.78



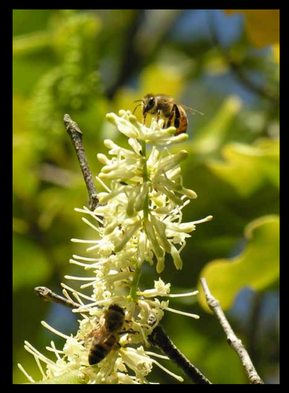
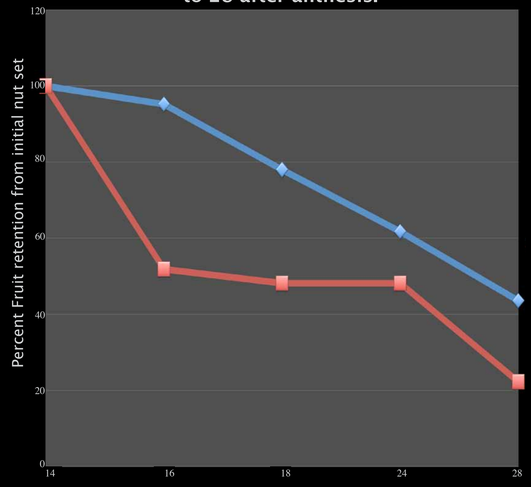


Table 1. Macadamia inflorescences and bee behavior

Inflorescence length	**15.40 cm long (S.E. 0.54)**	
Average number of flowers per inflorescence (Waimanalo)	**187.29 (S.E. 5.38)**	
Average time bee foraging for nectar spent/ inflorescence (Waimanalo)	8am-9am: 111.6 sec	10:30am to 12:00pm: 35.14 sec
Pollen collection (Waimanalo)	Foraging bees from a hive often tend to favor collecting nectar over pollen. Preliminary information suggests 1 out 10 foraging bees were collecting macadamia pollen.	

Frigure 2. Percent of fruit abscission from day 14 to 28 after anthesis.



Results and Discussion

- The amount of variation for both inflorescence length and number of flowers per inflorescence was relatively very small. Using a sample of 24 inflorescences we calculated the Coefficient of Variance (Cv) for inflorescence length and for the number of flowers per inflorescence, Cv = 0.171 and Cv= 0.140, respectively.
- Because of the low variability expressed by the inflorescences in flower numbers we estimated nut set by counting the number of fruits/inflorescence.
- There was a statistically significant difference in the average nut set between the open pollination group and the bee exclusion group (Mann-Whitney Rank Sum Test T=393, P<0.001, Fig. 1).
- A high rate of nut abscission among the two groups was observed (Fig. 2), however, 28 days after anthesis inflorescences exposed to open pollination had on average twice as many fruits as the inflorescences without the benefit of honey bee pollination.
- Six Diptera species and one Hemiptera species were observed visiting the flowers.

Our results showed that macadamia nut yield was higher when insect pollinators had access to the flowers. Bee exclusion experiments produced a sharp decline on the initial nut set of the experimental racemes. A high level of fruit abscission after an initial peak of nut set is common and suggests that Macadamia trees may selectively abort certain fruits. Abortion levels may be influenced by weather, nutrition, insufficient pollen transfer and overall lower nut quality (Sakai and Nagao, 1985, Trueman and Turnbull,1994). The higher abortion rate of bee exclusion flowers observed in this study may be related to a lower quality of the self pollinated fruits.

Honeybee pollination plays an important role in the yield and quality of Macadamia nuts and as the Varroa mite spreads across the Big Island of Hawaii, both farmers and beekeepers need help maintaining healthy strong colonies for pollination.

Future Research

More work is needed to elucidate the pollination requirements of the many Macadamia nut varieties. Information relating to hives/acre of macadamia plantation and the degree of cross pollination provided by bees will be invaluable for growers and beekeepers state wide. In addition, it would be useful to quantify the role that the less common insect visitors play in the cross pollination of Macadamia flowers.

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